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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

TECHNICAL MEMORANDUM 66

MANOMETER FOR RECORDING AIR SPEED.

By

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MANOMETER FOR RECORDING AIR SPEED.*

Pressure gages are largely used for measuring the speed of an airplane with reference to the air (actual speed), in which connection the pressure difference is measured with the aid of a manometer. This pressure difference in some forms of the instrument (for instance, Prandtl's pressure gage) gives the pressure directly, but in other forms is proportional to it. If it is desired to record the pressure difference given by the gage, the manometer must answer the following conditions:

1. It must respond quickly so that all speed variations will be correctly recorded.

2. It must not be affected by rectilinear or curvilinear accelerations. Hence, movable parts must be counterbalanced.

On account of the smallness of the pressure to be measured (the dynamic pressure being $q = 156\ \mathrm{kg/m^2} = 1/64$ atmosphere, with air density $\rho = 1/8$), the friction of the movable parts of the instrument must be eliminated as much as possible. Since the dynamic pressure is obtained as the difference between the total pressure and the static pressure, there are two pressures to be measured. In the present instance, this is done by conducting the total pressure under a box made of very flexible membranes (Fig. 1) while the static pressure is made to work on the cover of the box by inclosing the whole instrument in an airtight case, in which the static pressure

*Taken from "Zeitschrift für Flugtechnik und Motorluftschiffahrt," 1921, No. 1.

rules. In this way, only the difference of the pressures affects the cover of the box. The pressure exerted on the cover is received by a spring. The box is so thin that no appreciable elastic reactions are produced, provided the forces act for only short distances. Hence the distance traversed from the cover of the box is proportional to the dynamic pressure. This distance is enlarged by the lever shown in the diagram and recorded on a drum. If only a short distance is left to the box and this distance is correspondingly magnified by a light lever, a short oscillation period is obtained and a correspondingly rapid response of the instrument.

In order that no acceleration may affect the instrument readings, the following counter-balancing must be done. It is first essential to render rectilinear accelerations non-effective in both the horizontal and vertical directions. This is accomplished by means of the counterweights P_1 and P_2, which, in the acceleration of the instrument on account of its influence of inertia on the lever h_2, exert a moment offsetting the moment produced by the lever h_1, so that the pointer is not deflected. As regards the curvilinear accelerations, it is most important to offset those whose rotation axis is at right angles to the recording surface. These accelerations are rendered harmless by making the moments of inertia θ_1 and θ_2, of the levers h_1 and h_2, bear the same ratio as the lever arms a and b, hence $\theta_1 : \theta_2 = a : b$. The mass of the box cover, with half the mass of the box and the spring, is thereby to be included in θ_1. A curvilinear acceleration then generates in the connecting rod s a momentum coming from the lever h_1, which is of like magnitude but opposite in direction to the corresponding force from the lever h_1, so they mutually offset each other. In order that the inertia moments may satisfy the prescribed ratio, there are placed on the lever h_1 two like weights G equally distance from the pivot d_1. By varying the distance of these weights from d_1, the moment of inertia of this lever can be temporarily adjusted. Curvilinear accelerations about the other horizontal axis and about the vertical axis likewise generally produce moments on the lever axes. In order to eliminate the effect of these moments, the lateral positions of the counterweights P_1 and P_2, on the axis of h_2, must be so chosen that the moments arising on the lever h_1 will offset those on the lever h_2.

When employing the manometer on rapid climbing aircraft, still another precautionary measure must be taken, in order to avoid the variometer effect of the instrument, which is caused by the volume of the case being considerably greater than the volume of the box. If the instrument is placed, for example, where the external pressure is higher, a certain interval of time will elapse, on account of the compressibility of the air, before the higher pressure has reached a state of equilibrium in the case, while this takes place more quickly in the box, on account of its smaller volume. The result is a deflection of the manometer. In order to prevent this, the air is likewise admitted slowly into the box, which may be accomplished by placing a suitable valve in the air inlet pipe. The amount of the throttling depends on the resistance of the air inlet pipes to the instrument. Of course it also has the effect of damping the instrument, but not enough to affect its responsiveness very much.

The instrument was made in the workshop of the Göttingen aerodynamic laboratory. The box is made up of ring-shaped corrugated membranes of sheet brass 1/20 mm. thick, soldered to brass rings. The pivots of both levers consist of knife edges, in order to keep the friction as small as possible. They are held lightly against their supports by spiral springs. All the other joints consist of leaf springs. The measuring spring is removable, so that the measuring scale may be changed when necessary. The stylus is made very light of thin sheet aluminum. The record is made on smoked paper. The drum can be introduced or removed after removing the cover D. The clockwork which drives the drum can be started or stopped by turning a small eccentric button on the bottom. The valve for preventing the variometer effect is located at A.

The instrument gave a good account of itself in the trial flights made at the end of 1919 under the supervision of Professor Proell of the Hanover Car Works. Figures 2 and 3 reproduce two of the records, on which all the details of the pressure variations can be readily recognized. That the counterweights actually produced the desired effect is demonstrated by the fact that the record shows no trace of the engine vibrations, while the record of another manometer, not counterbalanced, was spread out by these vibrations in the form of a band. In squally weather, no utilizable record could be obtained with the latter instrument. The drum, driven slowly by the clockwork, was occasionally rotated slightly in the opposite direction by the very strong vibrations. This effect found expression in a peculiar wave form in the vertical lines (Figure 3).

Translated by National Advisory Committee for Aeronautics.

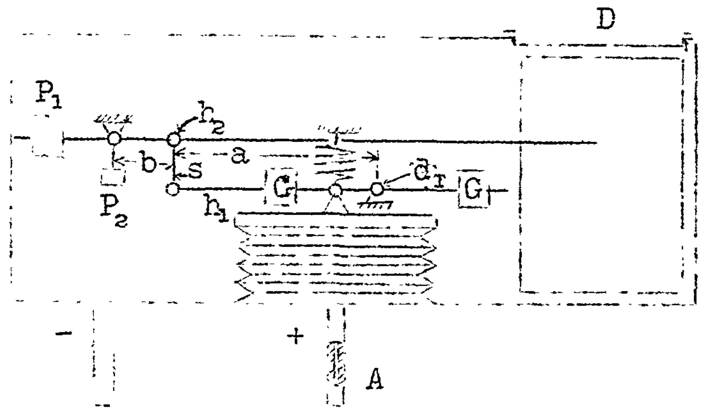

Fig. 1.

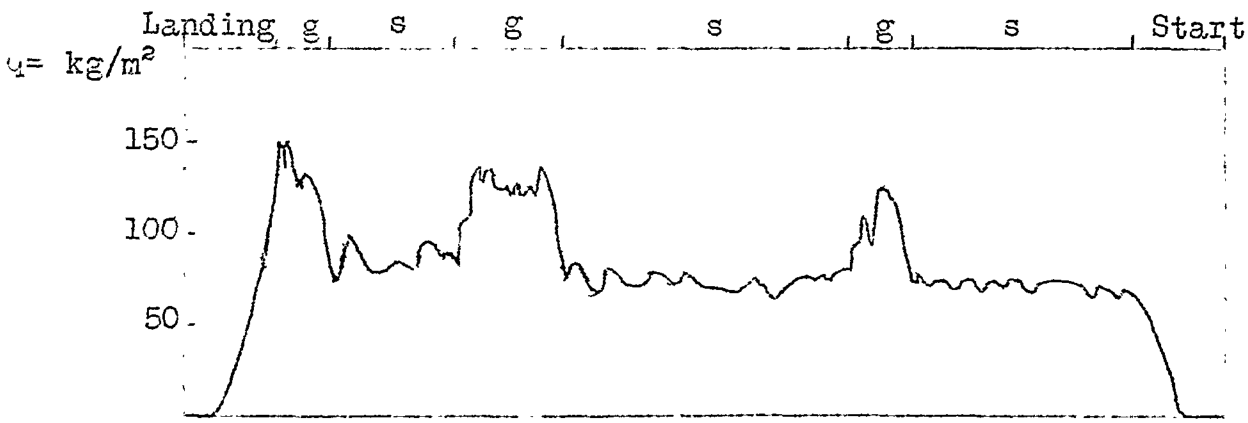

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Fig. 2. Flight with Hanover C L II. s = climbing.
g = gliding.

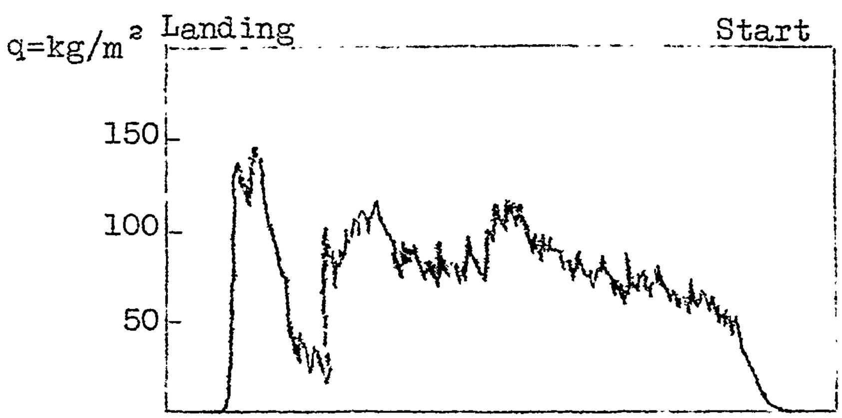

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Fig. 3. Flight with Halberstadt C L IV
in very squally weather.